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EROSION RESISTANT COATING TURBOSHAFT HELICOPTER ENGINE COMPRESSOR BLADES ESTIMATE AS MEANS OF ENGINE RUNNING TIME INCREASE IN SAND AIR ENVIRONMENT

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It is shown turboshaft engine TB3-117 compressor blades with erosion - resistant coating bench - tests results. Also it is carried out coating estimate as means of engine running time increase during operation in sand atmosphere.

Erosion - resistant protective coating turboshaft compressors blades is seen as one of effective means, has increased helicopter engine running time in sand atmosphere. At now effectiveness of protectve coating has esteemed by means of its wear resistance wich is greatly higher than construction materials one. But such point of view cannot permit to evaluate engine running time increasing in sand air environment due to erosion - resistant coating application.

So, it was carried out experimental exploration turboshaft TB3-117 compressor first stage imreller blades with erosion - resistant coating in sand air environment.

Experimental test bench and its main part schemes are shown on pic. 1 and 2. Aerodynamics tube to accelerate sand particles has 30 degree inclination angle (see pic. 2) to impeller front surface. It provides sand particles size 20...225 mcm relation speed V_{OTH} achivement till 370...440 meters per second, while blades tips speed value makes up 240 m/s; also it provides the same particles movement direction as real conditions one.

Sand conduction zone has 20 mm extent along blades height from tips (see pic. 2). Sand conduction zone relative value makes up 0.282 blades height. As abrasive has used quartz sand with particles size composition is shown in table 1. Particles size mean d makes up about 100 mcm.

Table 1

Particles size, mcm	5-40	40-70	70-100	100-140	140-200	200-250
mass, %	6,3	15,5	20,1	23,4	25,9	8,8

As an examples have given blades with TiN, VN protective coating and some else. During the experiment has received functions (dependences) of blades mass decreasing on mass of sand has passed through the compressor stage impeller $\Delta m_{Л}=f(m_{П})$. Experiment was continued till protective covers had weared compleatly. It was be recognized by wear speed equation for blades with erosion - resistant cover and without one. It should be emphasized, that blades with cover and without one were attached in the same impeller.

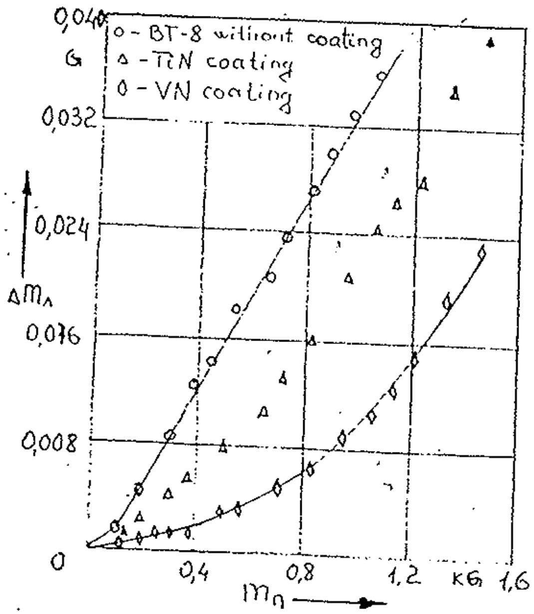
Some of results of the experiment for particles and blades impact speed V_{OTH}=265 m/s, (value of speed was determinated for particles 140 mcm size) are shown on pic. 3, the same one for V_{OTH}=390 m/s are shown on pic. 4. As seen on pic. 3 and 4, protective covers improve blades wear resistance. It causes function $\Delta m_{Л}=f(m_{П})$ move right on $\Delta m_{П}$ value - mass of sand, necessary for protective cover full wear by sand with definite particles size composition (pic. 5).

Value $\Delta m_{П}$ for V_{OTH}=265 m/s and blades with VN protective coating makes up about 0.70 kg. When impact speed V_{OTH}=390 m/s - value $\Delta m_{П}$ makes up 0.025 kg. As seen, effectiveness of protection covers increase grately with impact speed V_{OTH} descent (pic. 6).

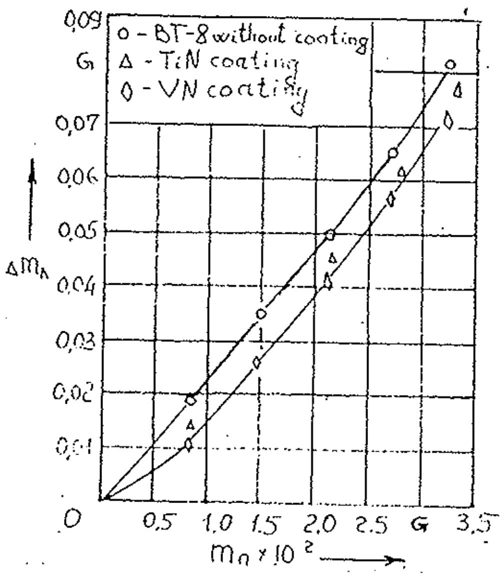
Investigation of particles size d influence on protective coated blades wear resistance has done for impact speed V_{OTH}=320 m/s. Some of results as function $\delta m_{П}=f(d)$ are shown on pic. 7.

Here $\delta m_{П}$ - relative increase of sand mass, necessary for protercive coating compleat wearing by fraction of sand with particles size d.

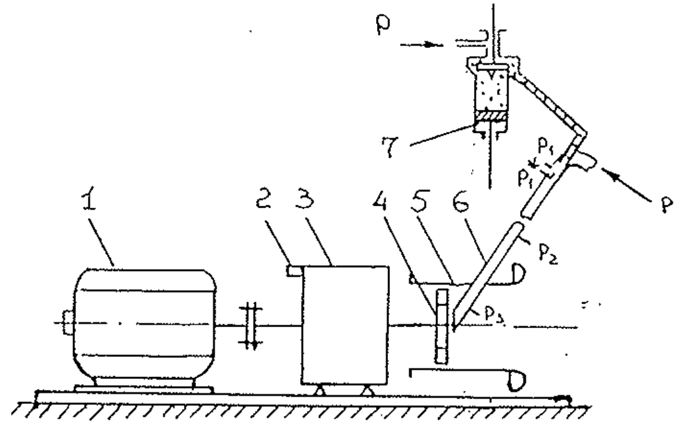
As seen from pic. 7, protective coating effectiveness



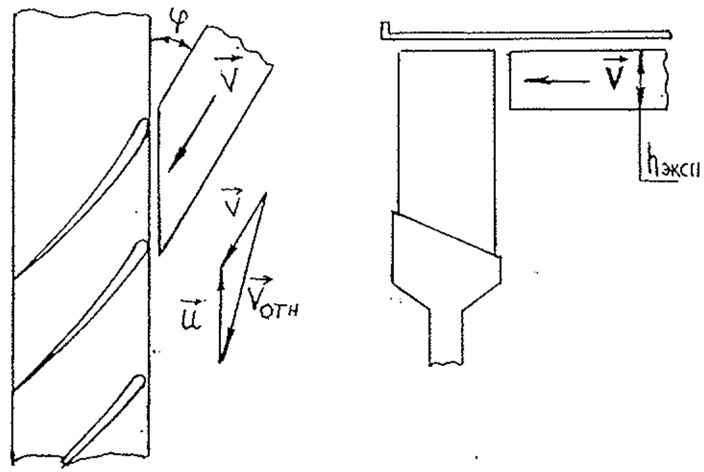
Pic. 3. Dependences of blades mass decrease on sand mass, has passed through the stage while V_{OTH}=265 m/s



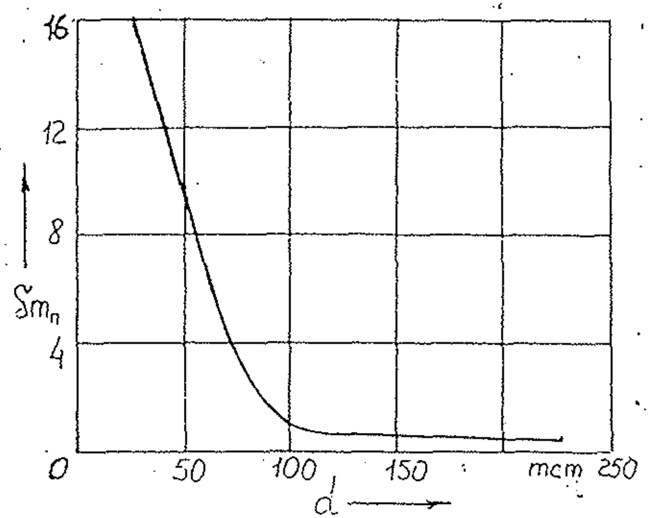
Pic. 4. Dependences of blades mass decrease on sand mass, has passed through the stage while V_{OTH}=390 m/s



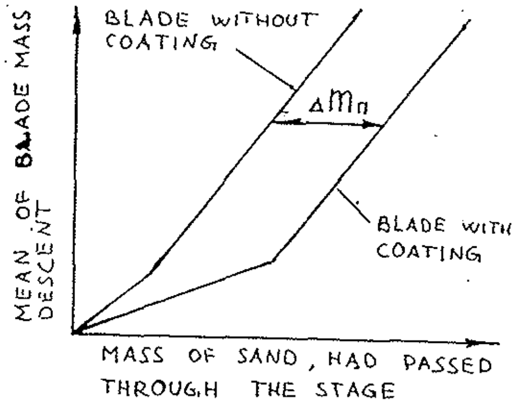
Pic. 1. Test-bench scheme: 1-electric engine; 2-revolution transducer; 3-revolution multiplication device; 4-impeller; 5-air intake device; 6-arodynamic tube (sand conduction tube); 7-sand supply device



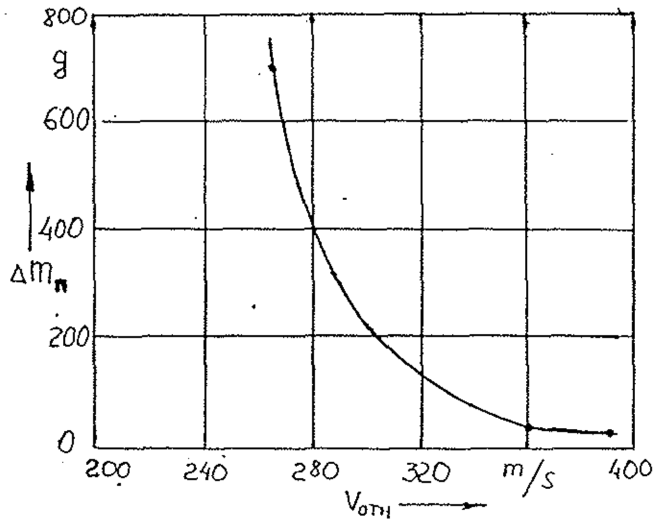
Pic. 2. Test-bench main part scheme



Pic. 7. Dependence of relative sand mass is necessary for protective coating compleate wearing on particles size; V_{OTH}=320 m/s



Pic. 5. Scheme, is showing result from erosion- resistant coating application



Pic. 6. Dependence of sand mass is necessary for protective coating compleate wearing as function of impact speed for 100 mcm particles size

is grately imroved with particles size descent, especially begin from d = 100 mcm and lower. It permit to suppose in axial compressor, where particles crush due to impact with construction units, and particles size descend from stage to stage, erosion - resistant coating would have the best effectiveness in the last stages.

Protective coating effectiveness estimate may be done by stage's relatively running time increase determination. Compressor stage running time without blade's protective coating may be calculated as follows:

$$\tau = \frac{m_{\Pi O}}{G_{\Pi}}, \qquad (1)$$

here $m_{\Pi O}$ - mass of sand, if passes through the engine, causes the failure of one, G_{Π} - sand mass flow rate.

If due to protection coating use mass of sand, causes engine failure increases on Δm_{Π} value (see pic. 5), then compressor stage running time increase value makes up

$$\Delta\tau = \frac{\Delta m_{\Pi}}{G_{\Pi}}. \qquad (2)$$

Compressor stage running time in sand air environment relatively increase may be determinated as follows:

$$\delta\tau = \frac{\Delta\tau}{\tau} = \frac{\Delta m_{\Pi}}{m_{\Pi O}}. \qquad (3)$$

It should be supposed, that sand particles distribution in front of impeller entranse is the same in both cases. So, it is necessary to definite Δm_{Π} and $m_{\Pi O}$ values.

Value of Δm_{Π} may be determined by using foregoing results of experimental exploration (see pic. 3,4,6,7,). To achive this aim it is necessary esteem sand particles and blades impact speed value in blades tips V_{OTH} (as the most abrasive wear take place in that place). Then by pic. 6 and 7 (the latest one is necessary for particles with size different from 100 mcm) corresponding value Δm_{Π} is determinated.

In case, when any particles distribution in front of impeller different from one in experiment take place value Δm_{Π} is marked as $\Delta m_{\Pi}{}^{\Pi P}$ and is determined as follows.

When sand conduction zone height $h_{\text{экcп}}$ is over than one in experiment

$$\Delta m_{\Pi}{}^{\Pi P} = \Delta m_{\Pi} \; / \; g \; , \tag{4}$$

here g - is relative part of sand mass, passing through zone, has height $h_{\text{экcп}}$. When sand conduction zone is h_{Π} less than one in experiment, then

$$\Delta m_{\Pi}{}^{\Pi P} = \Delta m_{\Pi} \cdot \bar{h} \; , \tag{5}$$

here $\bar{h} = h_{\Pi} \; / \; h_{\text{экcп}}$.

Value $m_{\Pi O}$ may be determined by using results of engine special experimental exploration in sand air environment [1]. As known, if 4.5 - 5.5 kg (it depend on particles mean size) quartz sand has passed through turboshaft engine TB3-117 , it cause compressor surge margin great descent and compressor surge (engine surge also) may occur.

To esteem 1-st stage running time increase may be got mean $m_{\Pi O} \approx 5$ kg. All calculations doing for VN cover.

Value Δm_{Π} has determinated by using functions is shown on pic. 6. For example, when V_{OTH}=320 m/s Δm_{Π} value makes up nearly 0.15 kg.

If sand particles uniform distribution along blade height take place, then g = 0,282 so

$$\delta\tau = \frac{0,15}{5 \cdot 0,282} \cdot 100\ \% = 10,6\ \%$$

If sand conduction zone height makes up 20 Sm (like in experiment), then g = 1. In such case

$$\delta\tau = \frac{0,15}{5} \cdot 100\ \% = 3\ \%.$$

Anological evalues may be done for any compressor stage in accordance with foregoing method (after corresponding impeller tests in sand atmosphere be done, like is shown before for 1-st stage).

Approximate stage running time increase $\delta\tau$ estimation for next compressor stages may be done by using foregoing 1-st stage tests results.

To be into consideration that particles size mean for group of the middle and the latest compressor stages makes up nearly 20 mcm [1], and sand conduction zone height formes nearly 5 mm (or $\bar{h}$ = 0,4) and Δm_{n} value (see pic. 6 and 7) makes up 2,5 kg (value is obtained by using 1-st stage tests results), we calculate

$$\delta\tau = \frac{2,5}{5} \cdot 0,4 \cdot 100\ \% = 20\ \%.$$

It should be emphasized, that value $\delta\tau$ = 20 % is understated esteem of engine running time increase due to erosion - resistant protective coating application, because of impact angles in this stages are grately lower than one in the first compressor stage.

Taking into consideration that turboshaft engine TB3-117 serviceability in sand atmosphere is limited by compressor surge margin, and descent of the latest one on design regime is determinated by erosion degree of the middle and the latest stages of compressor, then engine running time increase in sand atmosphere due to erosion resistant coating application, also is limited by the same compressor stages running time increase and makes up 20 % at least.

LITERATURE

1. Cherenkov S.V., Vlasov K.V. About helicopter turboshaft axial multistage compressor engine serviceability and state control improvement during operation in sand atmosphere. - The 1-st Forum of Russian helicopters Society materials collection. - M., 1994.